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Building Students' Scientific Literacy through Contextual Learning in the Physics Classroom

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Scientific literacy is an important issue in education today to face 21st century challenges which emphasize critical thinking, analytical skill, creativity, innovation skill, communication and collaboration. Therefore science teaching should provide students with these abilities. However, unfortunately most teaching methods in physics lessons are typically teacher centered and rote-learning based to enhance students' ability to answer the National Examination Test which focuses on basic skills, and memorization of formulas. However, the PISA tests, as an international assessment of scientific literacy, examine the student's ability to apply the knowledge gained to solve problems that he or she has not seen or solved before. The purpose of this research is to explore the phenomenon of building students' scientific literacy in the Indonesian context.

The methodological approach of this study was classroom action research, which emphasizes analyzing students' answers in particular topics in physics. This research was conducted in the science class of grade XI in Sukma Bangsa School. The teacher as a researcher delivered contextual teaching learning to enhance students' scientific literacy. The topics were gravity, simple harmonic motion, work and energy. The students' understanding were examined with the non-routine problem set. The way that student answered questions would reflect their conceptual understanding in physics. The students' scientific literacy level was assessed with the Bybee scale.

From this research, it was revealed that most of the students' understanding of physics was quite low. According to the Bybee scale, most of the students' scientific literacy level was nominal scientific literacy, while some students were still at the scientifically illiterate level. The students answered the physics questions based on their memorization not based on their conceptual understanding. Some of them used the "Plug and Chug" method and referred to the previous example. Students also could not explain the qualitative questions which explained cause and effect.

This study reveals that students have a lack of scientific literacy because there are so many basic problems in building students' scientific literacy, especially the basic skills in learning science, such as reading and basic math. The school should make a special program to improve the students' ability in basic math and reading. In addition, science teachers should give a rich text problem to accustom students to solving problems using conceptual understanding. They also should start giving high order thinking skill questions in order to build the students' conceptual understanding.

Key words: scientific literacy, contextual teaching and learning, conceptual understanding, Bybee scale, critical thinking, qualitative question, non-routine problem set

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1. INTRODUCTION

1.1 *Experience of being a teacher*

I have been teaching Physics in senior high school for ten years. From my experience, students have a perception that physics is a difficult subject to understand. According to them, physics is very confusing, with so many formulas and complicated mathematical calculations. I have tried hard to make my students engaged in my lessons, by making connections between physics with real life through a demo or an experiment. I have an eagerness to provide my students with an opportunity to get conceptual understanding in physics, encouraging them to understand the physical phenomena conceptually, not only with calculations based on formulas.

To assess the students' understanding, I usually give them questions which are referred to in the guidelines in national education policies. Sometimes to enhance my students' understanding, I offer them higher level questions. From my experiences, I recognize that students get difficulties in answering a question that needs critical thinking and also a question that is not similar to the previous example. They cannot relate the daily phenomena to the concepts that they have learned before. I also recognize that students tend to see the previous examples. It seems that they learn the physical concept by practicing in answering quantitative and repetitive questions, such as a question in the final examination and university entrance tests.

From these phenomena I realize that teaching physics is not only teaching students how to answer a question in an examination, but also teaching them conceptual understanding in learning physics. Teaching physics is not only exercises given to them in the form of problems which they are required to solve based on formulas and mathematical calculations.

1.2 *Common problems in a physics class*

Problems in students' conceptual understanding of physics are common in Indonesia. According to Diepenbork (2007), there are discrepancies between the intended curriculum and the implemented curriculum in the Indonesian educational system. Although in the new Indonesian curriculum the competency requirements seem to be similar with science literacy in the PISA, in the implementation, not all the curricular changes actualize in the teaching methods. Most teaching methods in physics lessons are typically teacher-centered. Teachers explain the phenomena and concepts, students write down notes and do the assignments. Because of the influence of the institutional system in the education system and assessment, the teacher's use of teacher-centered and rote learning based methods are emphasized to enhance students' ability to answer the questions in the National Examination test (Zulfikar, 2009). The problems that are given in the national test typically require calculation based on formula and algebraic manipulation without a deep understanding of the physics concepts. That situation makes the students feel that studying physics is just about calculation and there is no connection with their life. McNeil, as cited in Rohandi & Zain (2011) stated that the lack of connection between students' experience and classroom discourse could be the cause of the achievement gap.

Although Indonesian students often win a gold medal in an international physics competition (International Physics Olympiad), Indonesia has a low rank in international scientific literacy assessments such as PISA and TIMMS, even compared to the neighboring countries (Mailizar, 2013). From the results of the national examination in math and science, it seems that students' achievement is better than in the TIMMS (Hendayana, Supriyana & Imansyah, 2004). This is caused by the different difficulty level of the examination. In the national exam, the level of the test focuses on basic skills, memorizing formulas, and the type of the problems are the same as in the previous year's exam. However, the PISA tests examine the student's ability to apply the knowledge gained to solve problems that he or she has not seen or solved before. These different goals and the different levels of examination given make unsatisfactory assessment results in scientific literacy.

The lack of students' understanding in conceptual physics has not only been a problem for Indonesian students. Many studies in other countries show that the biggest problems in physics class have been in conceptual understanding in physics, especially in explaining physics' phenomena scientifically. Walsh (2009) wrote in his research that there was no significant difference in students' physics conceptual understanding in the Force and Motion

Conceptual Evaluation between students who had learnt physics at high school and those who had not.

1.3 *Conceptual change*

The 21st century challenges require the ability to make innovations based on thinking skills and deep understanding of the nature of science. This ability is used to face the economic, social, environmental, and humanity issues both nationally and on the international scale (OECD, 2015). Therefore, science teaching should emphasize the students' ability to analyze problems and find the ways of solving problems, not just a collection of the facts and the calculation of the mathematics based on formulas. This is consistent with the competencies required for scientific literacy: (Students) can explain scientific phenomena, evaluate, and design scientific research and interpret scientific data (OECD, 2015).

Therefore, conceptual change has to be the goal in my own teaching of students. The goal of learning physics is not only to solve a physics problem, but also to understand the world, and to learn how to solve problems in daily life based on the physics concepts that students have learned in the school. There must also be a conceptual change in teaching and learning physics in the schools and classrooms.

Contextual teaching and learning (CTL) is one alternative to create meaningful learning through a variety of active learning methods to engage a lesson with real world situations. This creates knowledge that students can apply in their lives (Sears, 2003). A basic theory for CTL is constructivism. Pritchard (2009, p.17) stated that “constructivists view learning as the result of mental construction. That is, learning takes place when new information is built into and added onto an individual’s current structure of knowledge, understanding and skills”. Thus, physics teaching should provide experiences that are related to the students’ daily experiences.

1.4 *Research Purpose*

This research aims to explore the phenomenon of building students’ scientific literacy in the Indonesian context. The research will focus on how students explain physics phenomena. The research followed the so-called teacher as a researcher model. The

researcher designed a contextual learning environment in the classroom through approaches such as problem based learning, cooperative learning, project based learning and authentic assessment. The research is expected to benefit the school's teaching and learning by offering new knowledge on the effectiveness of instructional methods and their relations to building students' capacity (conceptual understanding).

2 CONCEPTUAL CHANGE

2.1 *Physics teaching in Indonesia*

Before the implementation of new curriculum in 2013, physics was taught from seventh grade in junior high school until students graduated from senior high school. With the new curriculum, in junior high school, physics was taught and integrated with other science subjects such as biology and chemistry. But in senior high school, physics was taught as a separate subject as were biology and chemistry. Teaching physics in junior high school is usually more contextual than in the senior high school. Unfortunately, the contextual content has come from text books, therefore both teachers and students have just memorized facts. This is not only an Indonesian problem, since some research also reported it in other countries (Kasanda et al., 2005).

The objective of physics teaching as laid out in the national curriculum 2013 framework is to master the concepts and principles and have the skills to develop knowledge and attitude in preparation for continuing education at a higher level and developing science and technology (Kemdikbud, 2014).

Actually, according to the curriculum, the teaching in Indonesia is based on contextual learning, as the guidelines in lesson plan making state that in the learning process teachers must prepare lessons which contain the elements of REACT; Relating, Experiencing, Applying, Cooperating and Transferring as described by Crawford (2001). However, this concept does not run properly. The repetitive type of the national examination and university entrance test lead to a teaching and learning process that focuses on a rote learning process and drilling students' ability in answering the examination questions (Diepenbrock, 2005).

Physics teaching in senior high school has had lack of contextual content. It has emphasized more the use of a formula to solve the problem. Physics class is more like math class, due to the many formulas to be memorized and many calculations to be solved. Sometimes, in physics class, teachers explain the equation first and then explain the meaning

of the equation, instead of explaining the phenomenon then trying to formulate them into the laws of physics.

The traditional evaluation and routine problem tasks cause students to have a low ability in problem solving skills. The final test orientation has made the shift of the learning process purpose from ‘learning to understand the physics concept’ into ‘learning to proficiently solve the question task’.

Generally, the purpose of drilling students’ ability to answer examination questions became a profitable business for non-school institutions (Bimbel, the institution where students get extra lessons after school). In this institution, students actually are trained to solve the problems as quickly as possible without considering a concept, but by just memorizing the pattern of a question. This phenomenon causes students to have lack of conceptual understanding. Even though they have solved thousands of questions, if they were asked to explain the phenomena scientifically, they could not answer it. This has also happened in other countries, as reported by Kim & Park (2011).

According to Nizam (2016), the function of the national examinations has changed from 2015, since when the exam results are not used as graduation criteria but only for quality mapping. This change gradually started to improve the integrity of the national examination, since cheating on the exam was a big issue. Some high order thinking skill questions that require analysis skill have been inserted in the national exam. The national exam also applied an integrity index of the national examination, which measures the reliability of the examination. The school examination results with a high integrity index show the same trend with the latest PISA results (Nizam, 2016).

Due to the change in examination trends that required high order thinking skills, physics teaching and learning should engage students’ conceptual understanding. In the teaching process, students should not only be passive learners and just listen to clear explanations from the teacher, but also use their thinking skills to build their understanding. As suggested by Rusli (2012), teachers should embed daily life experiences as teaching material, such as science articles in newspapers, as discussion topics. He also suggested that teachers should not put emphasis on complicated calculation but more on students’ understanding of concepts and interpretation of the result.

2.2 *Students' approaches to problem solving*

Even though problem-solving skill in physics is not the main purpose in physics teaching, it can measure the level of students' understanding (Ibrahim & Rebello, 2013). There are many studies that have examined students' methods in solving problems that show their level of understanding. Most students start the procedure by making the unknown and given variable list that had been learnt from elementary school (Snetinova & Koupilova, 2012). This procedure is not bad. It is only an initial step to solve problem. As revealed by Wenning (2002), it is a common procedure in problem-solving in physics, starting from identifying known variables and unknown variables and then finding the mathematical relationship between them and solving the solution for the unknown variable. The problem in this procedure is determined by the equation that represents the relationship between two variables if the relationship is only defined by one equation. At the lowest level of understanding, some students even use a "plug and chug" approach, which just substitutes the known variable into a similar variable in the equation to find a solution or to remember the pattern of procedure in solving problems, or pattern matching methods (Heller & Heller, 2010) in which students refer to previous examples in the classroom or in text books to solve the problem in the test.

However, the procedure mentioned before lacks basic concept understanding. It just emphasizes mathematical procedure (Zewdie, 2014). Students should know the physics concept behind the formula. A qualitative approach should be involved in problem solving procedures to gain the conceptual understanding of physics. A more complex step in the problem-solving strategies which were advised by Heller et al. (1990) was an alternative way to attach the conceptual understanding to the problem-solving. First, change the problem statement into a visual problem situation. Second, explain the problem in the physics concept. Third, choose the appropriate solution or equation. Fourth, achieve the solution through the calculation and last, check the answer in a reasonable physics sense. These procedures are more complete because they involve qualitative processes that represent the physical process in the problem and require physical concepts.

There are many other problems that usually appear in physics problem solving. For example, students get difficulties in qualitative questions, because qualitative questions need a conceptual understanding, not only the use of a formula (Tao, 2011). Students are also more comfortable if the question is in numeric format rather than in symbol format (Torigoe & Gladding, 2007).

2.3 *Conceptual change*

Conceptual change is an acceptance process of new ideas because the idea was rational and understandable through the inquiry of learning activities (Posner et al., 1982). Students in the learning process do not always come with empty concepts that only receive the new idea that is given, but students often have had initial concepts for a particular topic (Fensham, 1982). Students' initial concepts could be helpful in the formation of conceptual change. On the other hand, it could be a barrier if the new understanding conflicts with previous student understanding.

Ideas can be accepted through assimilation if new ideas are consistent with the previous ideas or accommodation. If previous ideas cannot satisfy them, they will change their understanding with a new concept (Posner et al, 1982). According to Posner, there are four conditions that allow the conceptual change to happen. They are the dissatisfaction with an existing concept, a new concept is more clear and understandable, the new concept seems to be reasonable, and the students feel the benefits of the new concept. The awareness of the dissatisfaction with the existing concept is derived from the learning process.

Learning is a process that follows some specific criteria, such as learning involves change, is a continuous process and a learning process occurs if there is experience (Schunk, 1996). The purpose of learning is to convert someone's state from "do not know" to "know". Learning requires a process of building understanding from inside the learner themselves. According to conceptual change terminology, learning is not only a process to acquire facts without fundamental change in knowledge structures. (Disessa, 1993).

Constructivist theory strongly supports the formation of conceptual change as described previously. (Pritchard, 2009) declared that learning was a result of the mental construction process, when new information is added into individual prior's knowledge, understanding, and skills. The result is best when learners actively built their understanding. There are four basic principles in constructivism stated by Fosnot (1989). Learning is influenced by students' preconceptions, new understanding is formed if the students adopt new ideas, put more emphasis on the innovation rather than the collection of facts, and lastly, meaningful

learning happens if there was a friction process between the prior concepts with a new concept that built the new concept.

Hover (1996) argued that there are several criteria in learning process in constructivist theory, specifically, the construction process of learners' understanding based on their prior understanding, and that learning is an active process of learners to construct their understanding. These force teacher to make the learning process not just a transfer of information from those who have the knowledge to those who did not have the knowledge, but rather guiding students to test their understanding that already exists. The learning method that is suited to these criteria is contextual learning.

2.4 Contextual teaching and learning

According to Gilbert (2011), the problems of science teaching are learning objectives which are not clear, overloaded topics and material, the content of the topics is not related with the students' everyday experience, and learning is not delivered in the latest context. Otherwise students tend to achieve a higher knowledge level if the learning process contains connection between the lesson and everyday life (Sears, 2003).

The basis of contextual learning is constructivism, meaning that students build their understanding from both their current understanding and their experience. Contextual learning is a learning process that attempts to make connection between concepts and students' daily experience. Lynch, R. L., Padilla, M. J., Harnish, D., & DiStephano, C. (2001) explained that the principles of contextual teaching was that teachers should associate the teaching materials with their usefulness in everyday life and help students to apply the knowledge and problem-solving skills that they have learned in the classroom in the context of everyday life and preparation for the future.

Contextual teaching and learning (CTL) has been discussed before. According to Lynch & Harnish (2002) there are seven strategies for contextual teaching and learning such as problem-based learning, project-based learning, work-based learning, service learning, cooperative learning, inquiry-based learning, and authentic assessment. Problem based learning is learning that uses real-world problems as a context for students to think critically and to build problem solving skills. Work-based learning is learning that enables students to use context in work situations to study subject content. Otherwise, according to Smith (2012) inquiry-based learning is a teaching and learning strategy which involves students actively to

build their knowledge through inquiry. It is based on a scientific method, but not only happens in the laboratory or work groups, but also comes from teacher questions that inspire students to think. Cooperative learning is a learning process in which students work together to gain the learning outcome. Authentic learning is learning that enables students to learn in real terms or in an everyday life context. Problem-based learning is learning that challenges students to solve problems in real life.

Contextual teaching and learning could develop students' critical thinking and their ability to face their daily problems (Medrich et al., 2002). Through CTL, students are expected to have a conceptual understanding of physics, and therefore it will build the students' scientific literacy. Basically contextual teaching learning has its own characteristics, as described by Blachart (2001), the learning emphasizes the students' problem solving ability, teaching and learning in the daily context, educating the students to be self-regulated in the process of learning, linking the learning with a variety of contexts, facilitating students to work together in the learning process and applying authentic assessment.

3 SCIENTIFIC LITERACY

3.1 *What is scientific literacy?*

Scientific literacy is generally defined in various terms. Scientific literacy is an important issue in education today. It is even often used as a global indicator of the success of the quality of education in many countries. Indeed, the results of PISA and TIMSS are also often used as the reference for government to make policy in the education field.

According to the American Association for the Advancement of Science (AAAS), the objective of scientific literacy is to equip students with scientific knowledge in preparing students to become members of the community who are ready to face the global challenges, such as environmental issues, availability of energy, rapid population growth and more. These challenges could be overcome if people are literate in science, and have scientific habits in solving problems.

In the *National Science Education Standard* (1996, p:22-23),

“Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.”

According to PISA (2015, p. 7) the definition of Scientific Literacy is as follows:

“Scientific Literacy is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. *A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology which requires the competencies to:*

1. Explain phenomena scientifically:

Recognize, offer and evaluate explanations for a range of natural and technological phenomena.

2. Evaluate and design scientific enquiry:

Describe and appraise scientific investigations and propose ways of addressing questions scientifically.

3. Interpret data and evidence scientifically:

Analyze and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions. “

Krajcik & Sutherland (2010) propose five strategies to build students’ scientific literacy: (a) try to make a correlation between a new idea with students’ prior knowledge.(b) propose questions in the learning that are close to students’ lives, (c) make an interconnection in many contexts (d) give a chance for students to use science ideas (e) involve the students in the science class

3.2 Why scientific literacy is important

Why is scientific literacy urgent in the physics classroom? As explained in OECD (2015), to face the 21st century challenges, learning and innovation skills, critical thinking, analytical skill, creativity, communication and collaboration are needed. James Rutherford, as quoted by Thier & Daviss (2002, p.10) stated that “*Science is not a list of facts and principles to learn by rote. It is a way of looking at the world and asking questions.*” . Scientific literacy is not only needed for those who want to be a scientist or engineer, but it is also needed to be a good citizen and to deal with the latest issues.

The US government, through the National Research Council mentions that the importance of scientific literacy for the students, as quoted by Deboer (2000, p.590)

“: (a) Everyone needs to use scientific information to make choices that arise every day. (b) Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. (c) Everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world. (d) More and more jobs demand advanced skills, requiring that people be able to learn, reason, think creatively, make decisions, and solve problems. An understanding of science and the process of science contributes in an essential way to these skills. (e) To keep pace in global markets, the United States needs to have an equally capable citizenry”

Many authors explain the importance of scientific literacy in the various fields of life. Thomas & Durant (1987) as cited by Laugksch (1999), categorized the importance of scientific literacy into two groups; macro view and micro view. The macro view is related to the nation, in order to help the nation to compete in the economic world in creating new technological products and to market their products in developing countries. Countries whose citizens have high scientific literacy can make the right policies related to science, technology and society. The micro view is related to a person as a member of society, and makes them more competent and confident to face the competitive world of technology and also supports their career. It is also to support people to make wise decisions and lifestyles which are more environmentally friendly.

3.3 Research on scientific literacy in Indonesia

Indonesia has joined PISA assessment since 2000. The result shows that Indonesia ranks consistently in the bottom ten countries. Many studies on scientific literacy have been conducted both in Indonesian senior high schools and junior high schools. One of the example is research conducted by Rusilawati et al (2016) that tested students on four competencies in scientific literacy: science as a body of knowledge, science as a way of thinking, science as a way of investigating and interacting with science, environment, technology, and society. The research found that the level of all of the four competencies of

Indonesian students was low. This result is in line with Ariyanti et al (2016) who examined high school students scientific literacy using the Nature of Science Literacy Test (NOSLiT) . Similar research was also conducted by Diana et al (2016) that tested the students 'scientific literacy using scientific literacy assessment (SLA). The result showed that from the cognitive domain, thinking scientifically was very low. This poor grade for Indonesian students was caused by the teachers' lack of ability, overload of content in science subject, and a teacher oriented instructional method (Hayat, 2010).

3.4 Scientific literacy and reading proficiency

The low rank of Indonesian students is not only in science and math, but also in reading literacy. From the first time Indonesia joined PISA, the result was similar in science and math, always in the ten lowest. As a comparison, Indonesian students' reading literacy rank in 2015 was 64th of 70 countries, meanwhile in science Indonesia's rank was 62nd of 70 countries (OECD). This result was not surprising, because the questions in the PISA test required the ability and accuracy to understand the content of reading, and Indonesian students are not accustomed to solving rich-context questions. Sometimes, the content in the text was represented in graphs and tables (Rustaman, 2006). Language is also a tool for scientists to propose a hypothesis, draw conclusions and propose discoveries or new theories. Language is also a tool for students to read, collect and analyze information from various sources. (National Research Council, 2012)

As shown in the research of Hurley & Henry (2015), the main problem in their students in studying physics was not mathematics skill but it was language skill. Language skill is very important for understanding the text, interpreting the data and explaining the phenomena. Especially in teaching and learning, students read, write and listen to new information. Many words in science are difficult and uncommon, and have certain senses in science. For example, "vacuum" could represent the very low pressure in kinetic gas theory topic or represent there is no air friction in mechanics. No wonder that Wellington (2001) states in his book that language is the main factor that causes students' difficulties in studying science. To understand and to learn science, students must have ability in language and ability in mathematical applications. Here, language skills include the ability to read and write in the language of physics and the ability to describe or explain the phenomena of science NGSS (2013).

3.5 *Scientific literacy assessment in the physics classroom*

Students' scientific literacy level is assessed in various ways and aspects. For example, assessment which determines the ability of students in applying the science concept in an everyday context (Fensham & Harlen, 1999). There have been many standardized tests to assess students' scientific literacy levels, such as the international assessment PISA. Another standardized test for students is NoS, which measures the students understanding and attitude toward science and students' understanding of science and attitudes toward the science-technology society (STS). There is also an assessment which measures the views on the science and technology society (VOSTS) that was built by Aikenhead & Ryan (1992).

Teachers can make their own assessment to examine the students' scientific literacy in the physics classroom as long as it measures the content of knowledge of students, because that is the main part of scientific literacy (Laugksch & Spargo, 1996). The assessment also examines the students' competency in applying the proficiency in reading and writing, and also to analyze the scientific news (Phillip & Norris, 1999). Therefore, the assessment in this research focuses on content-knowledge which is in accordance with the topic being taught but still makes connections and correlations with everyday life.

These assessments are in line with the physics curriculum in Indonesia and aspects of scientific literacy, especially the ability to explain the phenomena scientifically and make an argument in drawing a scientific calculation. The assessment during this research was not to represent the level of scientific literacy but to examine how far the conceptual understanding of physics will contribute to scientific literacy. The assessment should add an alternative problem to increase students' conceptual understanding. The characteristic of an alternative problem is a problem that requires a conceptual understanding to solve it, not only using a formula and following the routine procedure to find the result (Henderson, 2005). Therefore, students can build their understanding through applying their concepts in solving a problem and facing the future challenges. According to Tao (2011) qualitative questions also can enhance students understanding, because the students should explain by using their conceptual understanding, and not only depend on the formula.

4 METHODOLOGY

The methodological approach of this study was classroom action research, which emphasizes analyzing students' answers in particular topics in physics. I chose classroom action research because as a teacher, I wanted to understand what kind of problems I have in my class and how I can improve my teaching. Mettetal (2012) explains that classroom action research is an effective way to improve our teaching because we know what the impact to our students is from our particular actions. Even though teaching methods are something that we can learn from books or journals, however every classroom, every student, and even every teacher have their own characteristics (Stringer et al, 2009).

In this research, I conducted teaching and learning in the classroom by using contextual teaching. The topics were gravity, simple harmonic motion, work and energy, which were according to the curriculum timeline. In every topic, the lesson was conducted based on contextual learning, which depended on what methods suited those topics.

4.1 *Participants*

To investigate scientific literacy in the physics classroom, the research was conducted in the second grade in the science classes of a senior high school. There were 42 students, who were divided into two classes based on their academic level due to the school policy. Class A was for upper academic level and class B was for lower academic level. The school decision to divide the students based on their academic level was aimed to help the students to learn easily based on their abilities and to prevent a big gap in the academic achievement. There were 11 male and 11 female students in class A, otherwise in class B there were six male students and 14 female students.

From the questionnaire I ran before starting the action research, there were only 20 out of 37 students who were interested in studying physics. Furthermore, when I asked “ If

physics was not a compulsory subject, would you still take a physics class?”, only 17 out of 37 students answered that they would still take a physics class even if it was not a compulsory subject. In contrast, only three students answered that they did not have difficulties in studying physics. Moreover, when I asked what factor could help them in studying physics, 16 students answered that memorizing the facts and concepts enabled them in studying physics.

4.2 *Data gathering methods*

The data was collected during the teaching and learning process, especially the students’ answer sheets. There were three topics conducted in this class: gravity, simple harmonic motion and work and energy. Every topic was taught by using contextual learning.

4.2.1 *Gravity*

In the Newton's laws of gravity topic, the learning is often delivered through lecturing methods, because this topic involves a force that cannot be measured directly. In the syllabus, Newton's laws of gravity consist of three indicators - the force of gravity between the particles, the gravitational field and the Kepler laws. In this research, I used an inquiry-based learning with observation approach.

Session one

For this topic, I gave an introduction by watching two short movies about space and gravity. The movies titles were, “*Brian Cox Visits the World's Biggest Vacuum Chamber*”, and “*The BEST TOUR of the International Space Station*”. The first video showed that Brian Cox visited the biggest vacuum chamber in the world at the NASA facilities center. This video showed the demo about the drop of a feather and bowling ball before and after air was pumped out from a chamber. The second video was about touring at the international space station, and the video showed how an astronaut lives in the international space station. From these videos, students could see and observe the recent issues relating to gravity in science and technology.

While watching these videos, the students looked very enthusiastic. They watched the videos as enthusiastically as watching movies. After watching, I asked them to discuss about

what they had seen in the video for five minutes. The class discussion was very intense, and students actively involved in the discussion; they asked everything concerning the content of the videos, and some students tried to answer their friends' questions. All students were involved in the discussions actively; even students who were usually passive in class took part in the discussion and were confident in giving their arguments. After they had the discussion, I asked them four questions that were related to the videos. In answering the questions, students were expected to use any information, to make conclusions from the videos, and to analyze it based on their prior knowledge.

Session two

In session two, the contextual teaching and learning was conducted by using *PHET interactive simulation* from <https://phet.colorado.edu> as a medium to explain the gravity concept to students. This simulation showed what variables will influence the gravitational force between two objects. Students discussed and made a conclusion based on the simulation. In this discussion, students were expected to have an understanding that the gravitational force between two objects is influenced by the masses of the two objects and proportional inversely to the square of the distance between the two objects. Based on the simulation, students were able to derive the gravitational force equation.

The class was also using a simulation from *Astro UNL* website, which described the motion of a planet around the sun and the Kepler law. After they observed the simulation, students were asked to derive the third Kepler law by using the gravitational force equation between the sun and the planet and the planet's centripetal force. In this process, students were expected to train algebraic manipulation capabilities related with physics principles. The students should know the concept behind the formula and how to find that formula. Class discussion was conducted to build students' understanding of gravity and to emphasize students' conceptual understanding. The class discussion was also expected to clarify the students' misconceptions.

Session three

To check students understanding, a problem-set was given to students and they were instructed to solve the problem in groups. Each group solved a different problem and the results of their work were presented in front of the classroom and afterwards were corrected together. The question was about the application of gravity problems; some of the problems

were a routine problem, usually called a one-step problem. Some of the problems were challenging and needed a high order of thinking skill. Students were expected to solve the questions by using their conceptual understanding, without referring to the previous example. For the one-step problem, most of the students in class A could solve the problem by working in groups without asking for help from the teacher. In class B, most of the students had difficulties in solving the problem without referring to the problem-solved task.

Session four

To check students' understanding of the gravity topic, the students had a test. All the questions were dissimilar or different from what they learned previously to avoid the “copy pattern” procedure in solving the problem. Some questions were in a “qualitative question” form, which did not require any formula or equation to write the answers. Students should use their conceptual understanding. Some questions were “non-routine problem”, problems that were rarely asked in the national text book or in the national examination. They were allowed to open their notebooks or text books because the test required their conceptual understanding rather than their memorization. They were also allowed to use a calculator in case they had difficulties in calculating numbers.

Session five

Remedial teaching was conducted to reinforce students' understanding and to rectify misconceptions that appeared in the first and the second tests. Students were taught to work with qualitative questions by using physics concepts which do not only depend on formula. They were also taught to explain the formula quantitatively. The third test was given to test students' understanding of the concept of Newton's law of gravity. The questions related to conceptual understanding of the topic of gravity, to check if there were still misconceptions.

4.2.2 Simple harmonic motion

Session one

For the first session of the second topic, the lesson was conducted with laboratory experiments about simple harmonic motion. This experiment was group work based, which asked the students to work in the physics laboratory. In this experiment, they would examine

the harmonic motion for spring and pendulum. It was a non-guided experiment, for which there was no written procedure that students should follow. They were asked to examine the characteristic of simple harmonic motion for spring and pendulum. Students were also asked to investigate what factor influenced the period of spring and pendulum harmonic motion. Each group had to arrange their own procedure to conduct the experiment. They also had to examine the displacement versus time graph from the experiment.

Students were expected to know the harmonic motion exactly from the observation. They were supposed to understand why the simple harmonic motion's equation has a sinusoidal equation. Next, students made a report, which contained their own procedure and data observation. In the last ten minutes, there was a class discussion about their experiments and criticism of the simple harmonic motion graph. From the displacement versus time harmonic motion graph, it could be concluded that the general equation for simple harmonic motion was a sinusoidal equation. Students' laboratory reports showed that most of the students could not present the data in the appropriate table.

Session two

For the second session, the class began by reviewing the experiment result to explore the quantity and physical aspect in simple harmonic motion. Students were lead to find the period of simple harmonic motion from the sinusoidal function of displacement and applied the restoring force for spring and pendulum. By applying the restoring force in spring and pendulum oscillation, the relation between the period and other parameters were found. To check students' basic understanding, a simple test was given to the students. They had to do the test independently and they were expected to solve the problem based on their conceptual understanding without referring to the previous example question.

There were two questions, determining the period and the displacement equation from the simple harmonic graph. Although the problem was so simple, only a few students could answer the question.

Session Three

In the third session, most of the students were unable to answer the simple questions in session two, such as to retrieve the information from the simple graph of oscillation. Most of them were also unable to apply the physical concepts that they had learned recently or previously in solving a new type of question. In order to enhance students 'understanding, a review was done by using simulation from <http://www.cabrillo.edu> to make students more

engaged. Some examples of questions were also given and discussed by students to build their thinking skills. The students' understanding was tested by using two types of questions; basic questions and high order thinking skills questions.

4.2.3 Work and energy

Session one

For the third topic, I chose a collaborative learning through discussion group method. I chose this method to force the students to read a textbook and find some information and to learn from the textbook. The class was divided into five groups, and each group had to study one sub-topic. Each group had to try to understand their topic through reading a textbook and discussion. Every group should explain their understanding in front of the class.

Session two

For the second session, each group had to present what they learned in front of the class. The students should make their friends understand their presentation. In Class B, they tended to receive their friends' explanations. Therefore, the presentation took only one session. On the other hand, in class A, the discussion took two sessions. In each presentation, I clarified some of the students' misunderstandings. At the end of the session, the class made a conclusion about all of the topics.

Session three

For the third session, to examine their basic understanding, students were given 15 short questions about the topic that had been discussed before. They also had to answer the questions in 20 minutes. After they answered the questions they clarified their answers. To build their conceptual understanding, the students had to work in a group to solve a set of problems. Each group was given two questions. One was a one-step problem and the other was a more complex problem. Every group had a different set of problems and they had to discuss in groups to solve the problem and share their results in front of the class. It took a long time for them to solve the problems. Some groups asked for the teacher's help in solving the question, especially for a complex problem.

Session four

In this session, there was a presentation from each group, where they had to explain how they solved the questions. During the presentation, some group had misconceptions about their topic. Therefore, I had to explain more to make them understand. To enhance their understanding, I gave an extra problem-solved task to the students in class B.

To make the learning more contextual, I asked the students to make an “educational toy design” that showed the process in energy transfer. I told them the criteria of the toys. They should be portable, show the process in energy transfer, show the change from energy to working and should be installed properly. They also had to present their design in front of the class. I hoped that they would be able to build their creativity and apply their knowledge in a practical thing. At the end of the session, I gave a test to examine their whole understanding of this topic.

4.3 *Data analyzing methods*

Students’ answer sheets were analyzed to see how the students explained the questions, what their weaknesses were and if there were misconceptions in their understanding. Students’ scientific literacy level was examined with a scale suggested by Bybee (2010) that is suitable for science assessment in the classroom. The scale is:

1. Scientific Illiterate: Students do not recognize the concept needed to identify the question.
2. Nominal Scientific Literacy: Students recognize physics concept in the question, but have a misconception or give an inappropriate explanation.
3. Functional Scientific Literacy: Students have ability in explaining the physics concept correctly but in a limited scope and cannot explain the physics concept that contains two or more topics.
4. Conceptual and Procedural Scientific Literacy: Students have understood the science concept.
5. Multidimensional Scientific Literacy: Students have a comprehensive understanding of science and the application in technological and societal situations.

The Scientific Illiterate level is the lowest level in the Bybee scale followed by Nominal Scientific Literacy. Multidimensional Scientific Literacy is the highest level.

4.4 Research ethics

Before starting the research, I asked permission from the school to conduct the research in the Senior High School. The students and parents also signed the informed consent to represent their willingness to be involved in this research. This research considered the privacy and the confidentiality of the participants so that I used anonymity concerning participants' names. This research also tried to avoid plagiarism in writing and citing the ideas in various journals and scientific articles.

5 FINDINGS AND DISCUSSION

This study was aimed to examine how the students explained or answered the questions in physics tests and its correlation in building their scientific literacy competency. The way students answer the questions describes their level of understanding and scientific literacy level.

5.1 Students' scientific literacy Level

As previously discussed, this research used the Bybee scale to check students' scientific literacy level based on their answers. Therefore, some questions were asked of students to apply this scale, and their answers were categorized based on the Bybee scale.

5.1.1 Scientific literacy level in gravity topic

Questions number 1 to number 3 were qualitative questions, and students were expected to answer based on their prior knowledge and their observation. Generally, for these questions students' answers had the categories:

- Writing the wrong fact to explain the phenomena or writing a meaningless sentence was categorized as Scientific Illiterate (SI)
- Writing the correct fact, but did not explain the question or had a misconception in explaining the phenomena was categorized as Nominal Scientific Literate (NSL)
- Writing the correct fact and being able to explain the phenomena, but performing it in a limited explanation was categorized as Functional Scientific Literacy (FSL)

Question1. Why does the difference in time required for falling between the ball and feather in the chamber before the air is pumped out from the chamber exist?

Actually, this question has been asked in many courses. Teachers usually use a paper and a stone as a demo in the classroom. In this research, while students answered these questions, they were expected to use the information and make conclusions from the video they watched and analyzed based on their prior knowledge. As a result, their answers were divided into three categories:

- Scientific Illiterate (SI), for example: “the air influences gravity” and “ the air influences the mass and the shape of object.”
- Nominal Scientific Literacy (NSL), for example: “the air and the different mass influence the motion of object”; “the air makes more massive objects to fall faster”, or “the air pressure influences the motion of object.”
- Functional Scientific Literacy (FSL). An example of their answers was “the air gives the air friction or drag force, and this force is influenced by the shape and its weight.”

The distribution of the students’ scientific literacy level is shown in Table 1.

Table 1. Students’ scientific literacy level in answering question number 1

Level of scientific literacy	XA		XB		Total		Percentage
	Male (n=11)	Female (n=9)	Male (n=4)	Female (n= 15)	Male (n=15)	Female (n=24)	
SI	2	1	3	9	5	10	38 %
NSL	6	8	1	6	7	14	54%
FSL	3	0	0	0	3	0	8 %

Table 1 shows that students’ scientific literacy levels were mostly in the nominal scientific literacy category, followed by scientific illiterate. The majority of students in class B were at scientific illiterate level.

Question 2. When the chamber has a vacuum, why there is no difference in falling time?

This second question remained based on students’ observation of the first video, and their answers were based on their prior knowledge to explain the phenomena that they had just watched. The students’ answers were divided into categories:

- Scientific Illiterate (SI) , for example “there is no air, no gravity, so the mass of the objects is the same”; “no more air, so the mass of object would be the same”; and “no more air, so the gravity decreases”. There was also one student who wrote a meaningless sentence (even in Bahasa, therefore unable to translate).
- Nominal Scientific Literacy (NSL), for example , “there is no air pressure anymore”; “No more air to influence the friction, and the weight of object is the same”; and “the gravity is the same, the mass does not influence the motion”.
- Functional Scientific Literacy (FSL), for example, “,” there is no more air that disturbs the motion of falling object”; “No other forces that influence the motion”; “no more air that makes friction to the object”.

Table 2. Students’ scientific literacy level in answering question number 2

Level of scientific literacy	XA		XB		Total		Percentage
	Male (n=11)	Female (n=9)	Male (n=4)	Female (n= 15)	Male (n=15)	Female (n=24)	
SI	2	3	2	7	4	10	36 %
NSL	4	1	2	9	6	10	41 %
FSL	4	3	1	1	5	4	23 %

Question 3. Based on the second video, why does the water in the International Space Station go round and float?

The knowledge that everything in space (far from the planet) will be floating was a common truth, and most of the students had known about it, however, the fact that water goes round in international space seemed new for them. When students watched the video, they looked amazed and curious about what happened in the video. As in the previous questions, in this question students were also expected to explain the phenomena based on their prior knowledge. The students’ answer categories are:

- Scientific Illiterate (SI) , for example “ there is no gravity, so the mass is decreasing”;
- “ no gravity and big air pressure”; “ no gravity and CO₂.”
- Nominal Scientific Literacy (NSL), for example , “ because of no gravity”; “ no gravity and vacuum.”

- Functional Scientific Literacy (FSL), for example, “less gravity in space”; “less gravity and the surface tension keeps the water round”.

Table 3. Students’ scientific literacy level in answering question number 3

Level of scientific literacy	XA		XB		Total		Percentage
	Male (n=11)	Female (n=9)	Male (n=4)	Female (n= 15)	Male (n=15)	Female (n=24)	
SI	2	0	2	2	4	2	15.4 %
NSL	5	7	3	13	7	20	69.2 %
FSL	4	2	0	0	4	2	15.4 %

The statement that “there is no gravity” was not exactly true. In space, gravity is not exactly zero, but very small, and it depends on the position. Generally, from question number 1 to number 3, there were misconceptions found related with gravity:

- Gravity is influenced by air
- Mass of the object is influenced by gravity
- In outer space, the air pressure is high

The next question was given after the lesson. It was conducted by inquiry-based methods. Students learnt about gravitational force, gravitational acceleration or gravitational fields and also Keppler law. In this session, students also did some questions in group to build their understanding. To check their understanding, a test was given to the students.

For a quantitative question or a more complex question, based on students’ answers the level of students’ answers can be categorized as:

- Scientific Illiterate (SI): students did not recognize the concept in the question at all, wrote a random formula.
- Nominal Science Literacy (NSL): students recognized the concept to solve the formula, but made a mistake in procedure to solve the problem or had misconceptions.
- Functional Science Literacy (FSL): They recognized the concept to solve the formula, did the procedure correctly, did not have misconceptions, but only for a question that involved one concept.
- Conceptual Scientific literacy (CSL): They recognized the concepts in the complex question that involved many topics, made an inter connection between the concept and did the procedure correctly.

Question number 4. “Someone who believes that the earth is flat is asking you, if there is gravity, why is the balloon floating? Answer this question scientifically and prove it with a calculation. (hint: usually the balloon is filled with helium or acetylene gas (C_2H_2))” and the buoyant force is $F = \rho_f V_o g$).

This question combined two concepts, gravity and fluids. The buoyant formula was given as a clue. The density value of helium, acetylene and air were also given. The students’ answers can be categorized as follows:

- Scientific Illiterate (SI), for examples: “balloon filled with the helium is smaller than gravitational acceleration”; “helium will block the air into the balloon”, and many students did not answer.
- Nominal Science Literacy (NSL), for examples: “the balloon is filled with helium/ air, the helium is lighter than the air”; the students checked if there was a balance between the weight and buoyancy, but made a mistake in substituting the density value, and made a conclusion that the balloon is floating because it is light.
- Functional Science Literacy (FSL), for example “the balloon is filled with helium, its density will be lighter than the air. The balloon will move upward because the buoyant force is bigger than the gravity”, but they did not prove it with the calculation; other students wrote the balloon can be floating because the buoyant force is greater than the weight, but they made a mistake in substituting the variables.

Table 4. Students’ scientific literacy level in answering question number 4

Level of scientific literacy	XA		XB		Total		Percentage
	Male (n=10)	Female (n=10)	Male (n=6)	Female (n=14)	Male (n=16)	Female (n=24)	
SI	4	4	4	8	8	12	50%
NSL	4	6	3	5	7	11	45 %
FSL	2	0	0	0	0	0	5 %

Question number 5 “If the gravity acceleration (g) on the earth’s surface was 10 m/s^2 , what is g at height $3R/2$ (R , earth radius)?”

This type of question is actually a routine question, often asked in the national examination, but since the example had not been given before, most of the students were unable to solve the question. The students’ answers can be categorized as:

- Scientific Illiterate (SI), students answered with calculate R and wrote the equation that gravity acceleration between the two place is the same, and most students did not answer
- Nominal Science Literacy (NSL), students answered with making comparison between the two places but made a mistake in substituting R , just writing the formula, and did not know what to do
- Functional Science Literacy (FSL), students could answer correctly

Table 5. Students' scientific literacy level in answering question number 5

Level of scientific literacy	XA		XB		Total		Percentage
	Male (n=10)	Female (n=10)	Male (n=6)	Female (n=14)	Male (n=16)	Female (n=24)	
SI	5	1	5	12	11	22	57.5%
NSL	1	9	0	1	1	10	27.5%
FSL	5	1	0	0	5	1	15%

Question number 6. "A star with radius R , with mass concentrated in the center. If the gravity field in the surface was g , make a graph that describes the gravitational fields in the distance, R , $2R$, $3R$ and $4R$."

This question has the same content as question number 5, the comparison of g value in different places but in the symbol format. Students were also asked to draw a graph in four positions. They should calculate each g value by comparing with g value at surface. The students answers can be categorized as:

- Scientific Illiterate (SI), students just wrote the formula (it was an open book test), made a random graphic such as parabolic graph, linear graph, sinusoidal graph and even a step graph. Many students did not answer at all.
- Nominal Science Literacy (NSL), students tried to calculate the gravity field at each distance and draw the graph, but made a mistake in calculation.
- Functional Science Literacy (FSL), students calculated the gravity field at each distance, and drew the graph correctly or calculated the gravity field at each distance correctly, but in drawing the graph, using the an inappropriate scale therefore the graph was not correct.

Table 6. Students' scientific literacy level in answering question number 6

Level of scientific literacy	XA		XB		Total		Percentage
	Male (n=10)	Female (n=10)	Male (n=6)	Female (n= 14)	Male (n=16)	Female (n=24)	
SI	6	9	6	13	12	22	85%
NSL	0	2	0	0	0	2	5%
FSL	4	0	0	0	4	0	10%

Questions number 7 and number 8 were given in the third test, after reviewing all the material in the gravity topic and revising all the students' misconceptions found in the previous test.

Question 7. "If you are in the swimming pool, does gravity work there? Give a reason. And why are we floating?"

This question should have been easy for the students, since it was their daily life experience and they had learnt the Archimedes principle in junior high school before. The students' answers can be categorized as:

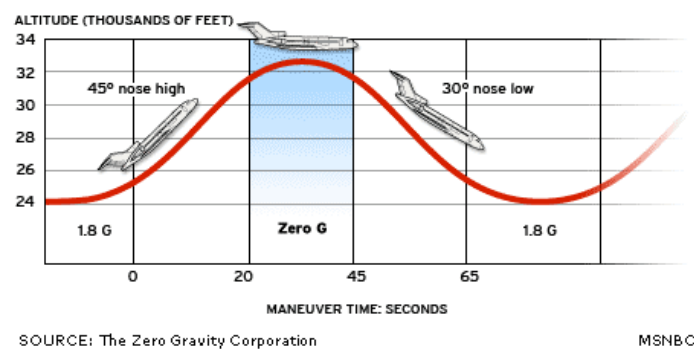
- Scientific Illiterate (SI): the answer that said gravity still works, but the reason contained misconception or wrong evidence such as because of hydrostatic pressure, because we are floating, because in the water our body was not floating at all. Surprisingly there were some students who that said gravity decreased or even not work in the swimming pool with the reason gravity was reduced by the water pressure, gravity did not work in the water.
- Nominal Science Literacy (NSL): the answer that said, gravity still works in the swimming pool and gave the appropriate reason that everything on the earth feels the earth's gravity, but could not give a reason why we were floating. There were so many misconceptions in explaining why our bodies float in the swimming pool. Some reasons were such as our body is weaker in the water, water mass is greater than our body, water mass is very high, there is air in our bodies.
- Functional Science Literacy (FSL): the answer that said, gravity still works in the swimming pool and gave the appropriate reason and could explain why we were floating. Unfortunately there were no students who could explain it.

Table 7. Students' scientific literacy level in answering question number 7

Level of scientific literacy	XA		XB		Total		Percentage
	Male (n=10)	Female (n=10)	Male (n=6)	Female (n=14)	Male (n=16)	Female (n=24)	
SI	6	8	4	11	10	19	72.5%
NSL	4	2	2	3	6	5	27.5%
FSL	0	0	0	0	0	0	0%

There were so many unexpected students' answers in question number 7 since it was related with students' daily experience. The students' misconception about the change of gravity in the swimming pool also has been found in Pablico (2010, p:39) such as there is no gravity in swimming pools or gravity decreases in swimming pools. No student could explain why our bodies are floating in the swimming pool which reveals that students could not explain the phenomenon beyond the concept being studied, even though the concept had been learnt before in junior high school or in grade X.

Question number 8. Zero Gravity Corporation is an American company that operates weightless flights. The flight lasts for 90 to 100 minutes and consists of 15 parabolic trajectories, each of which simulates the acceleration due to gravity on Mars (1/3 of the Earth's gravitational acceleration), the acceleration of gravity on the moon (1/6 earth gravity acceleration) and a weightlessness state. The figure below shows the path formed by the plane. Explain how to get the zero gravity condition and Mars gravity condition.



This question can be categorized as a complex question, combining two topics in one question. The content of question is a technological issue, students were asked to apply their concept to explaining how it could happen. The students' answers can be categorized as:

- Scientific Illiterate (SI): wrote the maximum height for parabolic motion, just wrote the equation for g , substitute $g = 0$ and $g = 1/3$ into gravitational acceleration formula, but most of the students did not answer the question.
- Nominal Science Literacy (NSL): recognized that this question was related with centripetal force but made a mistake in substituting the normal force value.
- Functional Science Literacy (FSL): recognized that this question related with centripetal force and could finish the calculation for zero gravity condition, but did not explain what the result meant.

Table 8. Students' scientific literacy level in answering question number 8

Level of scientific literacy	XA		XB		Total		Percentage
	Male (n=10)	Female (n=10)	Male (n=6)	Female (n=14)	Male (n=16)	Female (n=24)	
SI	8	10	6	14	14	24	95 %
NSL	1	0	0	0	0	0	2.5 %
FSL	1	0	0	0	0	0	2.5 %

In the gravity topic, there were so many misconceptions in students' answers, especially in answering qualitative questions. Such as the air influences the gravity, the mass influences gravity, we are floating in the water because there is no gravity in the water. Students also got difficulties if a question involved two or more concepts, such as in question number 4, 7 and 8. In question number four, solving the problem needed to correlate with the concept from the fluids topic. The buoyant formula was given as a clue, therefore students just need to substitute the value of variables in the formula. In the next test, the concept of buoyant force in gravity reappeared in question number 7, but in qualitative format. All students were unable to apply the concept in the fluids topic into the gravity topic.

5.1.2 Simple Harmonic Motion

Question number 9 actually is a simple question, This question was given in a short quiz in the second session of this topic just after discussing the concept of simple harmonic motion.

Question number 9: From the displacement versus time graph for simple harmonic motion.

a. Find the amplitude and period

b. Write the displacement equation that represents the graph

For this question (a) students answers were categorized as:

- Scientific Illiterate (SI): wrote time as period, wrote frequency equation $f = mg$ and did not answer the question.
- Nominal Science Literacy (NSL): seemed to know how to calculate the period from graph, but made a wrong calculation or wrote frequency as period.
- Functional Science Literacy (FSL): could find the information from the graphic to calculate the period.

Table 9a .Students' scientific literacy level in answering question number 9a

Level of scientific literacy	XA		XB		Total		Percentage
	Male N=10	Female N=9	Male N = 7	Female N=14	Male N=17	Female N= 23	
SI	5	5	6	14	11	19	75 %
NSL	4	4	1	0	5	4	22.5 %
FSL	1	0	0	0	1	0	2.5%

In the question 9b, students were asked write the displacement equation based on the graphic. Students should substitute amplitude and period from the graphic into the equation.

For this question students' answers can be categorized as:

- Scientific Illiterate (SI): calculated $x(1)$ until $x(4)$, but could not substitute the correct value for period, differentiate the displacement equation, Substitute T (period) with t(time) and also did not answer.
- Nominal Science Literacy (NSL): wrote the general equation $x(t) = A\cos(\omega t)$, but made a mistake in substituting the variable, seemed to know the procedure to answer, but due to getting the wrong T value, they could not get the right answer.
- Functional Science Literacy (FSL): did the right procedure and got the right answer.

Table 9b.Students' scientific literacy level in answering question number 9b

Level of scientific literacy	XA		XB		Total		Percentage
	Male N=10	Female N=9	Male N = 7	Female N=14	Male N=17	Female N= 23	
SI	1	1	5	6	6	7	32.5%
NSL	8	8	2	8	10	16	65 %
FSL	1	0	0	0	1	0	2.5 %

The next question was given in the fourth session of this topic, after topic review and discussing some examples of the question.

Question number 10: From the harmonic motion equation $x(t) = 4 \cos (6\pi t)$;

- a. *find the period and*
- b. *velocity at $t = \frac{1}{12}$ s.*

This question was quite similar with question number 9, but in different form. In question 9 the period was retrieved from the graphic, but in number 10 the period was retrieved from the equation. For question 10.a, students' answers can be categorized as:

- Scientific Illiterate (SI) : did not recognize the question as example, could not calculate the period, calculate the displacement by substituting $t = 1/12$., could not answer the question, identified amplitude as a period, wrote the equation $f = m a$
- Nominal Science Literacy (NSL) : Identified angular velocity (ω) as a period
- Functional Science Literacy (FSL): could find the period from the equation

Table 10a. Students' scientific literacy level in answering question number 10a

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	4	8	6	14	10	22	76.2 %
NSL	1	0	0	0	1	0	2.4 %
FSL	6	3	0	0	6	3	21.4 %

For question 10 b, students could answer the question in two methods, first by using the general equation for velocity or by deriving the displacement equation that was given. Students' answers can be categorized as:

- Scientific Illiterate (SI) : such as, did not answer the question, wrote the displacement equation again
- Nominal Science Literacy (NSL): such as, derived the velocity equation from displacement but made a mistake in substituting $\pi = 180^0$, used the general equation for velocity and could not substitute the right ω value
- Functional Science Literacy (FSL): could calculate correctly

Table 10b. Students' scientific literacy level in answering question number 10b

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	3	1	4	8	7	9	38.1 %
NSL	2	8	2	5	4	13	40.5 %
FSL	6	2	0	1	6	3	21.4 %

Question number 11: A mass M is suspended on a spring that has a spring constant k so that the system oscillates with a period T . If the mass becomes 3 times as before, what is the period of oscillation now?

This question is about the period of spring oscillation, which had been given before in the third session but in different format. In the third session the question was in numeric format, students calculated the period of the mass and spring constant given. On the other hand, in this question all the given variables were in symbol format. This is a simple question or one step-problem, students just needed to write the period of spring formula, and make conclusions based on the formula. Students' answers can be categorized as:

- Scientific Illiterate (SI) : such as the period is proportional to the mass, gave the wrong formula, wrote the displacement equation, wrote the equation $\text{Period}_{\text{initial}} = \text{Period}_{\text{final}}$, substituted the M value and no conclusion, some students also did not answer
- Nominal Science Literacy (NSL) : Student recognized the period of spring oscillation, substituted $3M$, but could not make conclusions based on the formula, student recognized the period of spring oscillation, but had no idea with the change of M
- Functional Science Literacy (FSL): Could answer correctly.

Table 11. Students' scientific literacy level in answering question number 11

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	3	2	3	7	6	9	35.7 %
NSL	6	8	3	7	9	15	57.1 %
FSL	2	1	0	0	2	1	7.2 %

Question number 12. A mass M is attached to a spring on the horizontal slippery floor. Then the mass M is pulled and released so that the system oscillates with amplitude A . If the maximum oscillation speed is V_m , determine the magnitude of the spring constant in the given term.

This question looks similar with question number 11, but is more complex and needs more than one procedure. Students should analyze what is the relation between mass M and maximum speed V_m . Students also should know how to get the maximum speed equation. Students' answers can be categorized as:

- Scientific Illiterate (SI): students just wrote one equation that had been written in the textbook, without performing mathematical operation on that equation. As example, just wrote the equation of spring period $T = 2\pi\sqrt{\frac{m}{k}}$, spring force equation $F = -Kx$, $k = m\omega^2$, constant and even no answer.
- Nominal Science Literacy (NSL) : recognized that this involved two equations, but could not make a correlation between them, such as writing the spring force equation $F = -Kx$ and the displacement equation $x(t) = A \cos(\omega t)$
- Functional Science Literacy (FSL): recognized that this involved two equations, made a correlation between them but could not finish the calculation, such as found the maximum oscillation speed $V_m = A\omega$, but did not substitute $\omega = \sqrt{\frac{k}{m}}$.

Table12. Students' scientific literacy level in answering question number 12

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	9	10	6	14	15	24	92.8 %
NSL	1	0	0	0	1	0	2.3 %
FSL	1	1	0	0	1	1	4.8 %

Question number 13: Given a picture that shows a father and son in the playground. The son plays on a swing, and his father keeps pushing him every time he gets back to the initial position. Describe what happens to the boy and draw a graphic that shows the displacement versus time.

Actually, students could answer the question if they had ever had an experience with playing on a swing or had even just seen it. Therefore students also could imagine what would the graphic could be. Based on daily experience, if a force is applied to a swing, every time the swing comes back to initial position, the amplitude of swing will be bigger. In scientific explanation, if a force is applied with the same frequency with the swing's natural frequency, the swing will resonate and its amplitude becomes bigger. Students' answers can be categorized as:

- Scientific Illiterate (SI): did not draw a graph or not explain what happened, drew a graphic not consistent with the explanation. For example, did not explain what happened and drew a graphic with constant amplitude, kept swinging, but drew a graphic with amplitude becoming smaller, back and forth with the same angle and same speed but did not draw a graph, the swing increased the speed and further distance, constant amplitude but period changed, drew two different graphics with a constant amplitude, did not answer.
- Nominal Science Literacy (NSL): drew a graphic correctly or explained what happened correctly. Some explained with an inappropriate sentence. For example, the swing would not stop, drew a graph with a constant amplitude, the swing was faster and drew the correct graphic, drew a graphic with a amplitude which became bigger, but did not explain what happened, the swing would not stop, drew the correct graph.
- Functional Science Literacy (FSL): explained what happened correctly and drew a correct graph. Example: "The amplitude is bigger if father keeps pushing and smaller if father is not pushing, with amplitude becoming smaller", and drew the correct graphic, "There was an influence from air friction to reduce the energy, therefore if father did not keep pushing the amplitude became smaller and became bigger if father kept pushing under a certain condition" and drew a correct graph.

Table13. Students' scientific literacy level in answering question number 13

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	5	5	6	12	11	17	66.7 %
NSL	4	5	0	0	4	5	21.4 %
FSL	2	1	0	2	2	3	11.9 %

5.1.3 Work and energy

The topic was conducted with cooperative learning methods with discussion group approach. They also had to solve some questions in groups to enhance their understanding and share what they had learnt in front of the classroom. Therefore students had experience in solving the work and energy question.

Question number 14: A car with 2000 kg mass move with the velocity 10 m/s. How much work is required to stop the car?

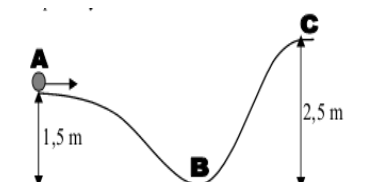
This question was a simple question or one step problem, in this concept, students just applied the concept that the work done on object is equal to the change of the object's kinetic energy. A similar concept had been done before in discussion groups but in different format. Students' answers can be categorized as:

- Scientific Illiterate (SI): wrote a random equation, showed that students had no idea of the concept behind the question, such as writing $w = mg$, $W = Fs = mgv/t$, ΔPE , $W = FS = Kx(x_2 - x_1)$, m/v . or did not answer.
- Nominal Science Literacy (NSL): recognized that this question related with kinetic energy, but had some misconceptions. Example: answered by using formula $W = KE$, "To get the final KE is zero, there should an opposite energy with the same amount with initial KE".
- Functional Science Literacy (FSL): students could answer by using the right concept.

Table14. Students' scientific literacy level in answering question number 14

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	2	5	3	5	5	10	35.7 %
NSL	2	1	3	6	5	7	28.6 %
FSL	5	6	0	4	5	10	35.7 %

Question number 15. A 2 kg object moves at 5 m/s at the point A, the object moves along the frictionless path as shown in the picture. If the gravity acceleration is 10 m/s^2 find the velocity at point C.



This question applied the concept of conservation mechanical energy. Students' answers can be categorized as:

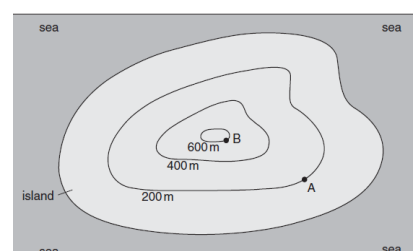
- Scientific Illiterate (SI): did not recognize that this question related with the concept of conservation mechanical energy, using another equation that was not related with the concept. An example: $KE \text{ at point A} = KE \text{ at point C}$, using a height comparison, using the work formula $W = \times s \cos \theta$, used a random formula and there was a student who did not answer the question.
- Nominal Science Literacy (NSL): students recognized the concept of conservation mechanical energy, but had some misconceptions. As an example: used law of conservation of energy, but stated that the initial speed was zero: used a shortcut formula, $v = \sqrt{2gh}$, a special case for zero initial velocity : made a mistake in substituting the height .
- Functional Science Literacy (FSL): students recognized the concept of conservation mechanical energy and applied with appropriate procedure.

Table15. Students' scientific literacy level in answering question number 15

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	1	3	3	1	4	4	19 %
NSL	2	3	2	9	4	12	38.1 %
FSL	8	5	2	3	10	8	42.9 %

Question number 16. The picture below show the contour map from an island. The contour line shows the same height.

- Calculate the work required to move the 50 kg object from A to B.
- Make an arrow to represent the flow of water from the highest place to the sea.



This question applied the work and the change of potential energy concept which is the example given before in the work group discussion. Because the students were not familiar

with the height that was given in the contour map, some of students could not answer this question. The students' answers could be categorized as:

- Scientific Illiteracy (SI): did not recognize the question correlated with potential energy, therefore some students did not answer or calculated by using mechanic energy = potential energy + kinetic energy.
- Nominal Scientific Literacy (NSL) : recognized that the question correlated with potential energy, but had some misconceptions, such as calculated by using formula $W = F \cdot S$, S is displacement, read the contour line as a distance , just calculated PE in one position, or just drew the water flow properly.
- Functional Scientific Literacy (FSL): solved the question with the right concept and drew the right graphic

Table16. Students' scientific literacy level in answering question number 16

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	3	3	3	11	6	14	47.6 %
NSL	5	6	3	3	8	9	40.4%
FSL	3	2	0	0	3	2	12 %

Question 17. The earth receives 1 kW / m² energy from the sun. A solar cell is able to convert 40% of the solar energy it receives into electrical energy. How much energy is generated by 10 solar cells with areas of 2 m² each ?

Even though this question contains a work and energy topic, this question could be solved by using everyday skills such as percentage and efficiency. The students' answers could be categorized as:

- Scientific Illiteracy (SI) : did not answer or used a random equation such as mechanical energy = $\frac{1}{2}$ 40 % , 40% x10, $p=10/n$, Total energy = energy input – energy output
- Nominal Scientific Literacy (NSL): recognized and calculated by using efficiency equation, but made a mistake in calculating energy for total cell.
- Functional Scientific Literacy (FSL): could answer correctly by using physics equation or mathematical logic

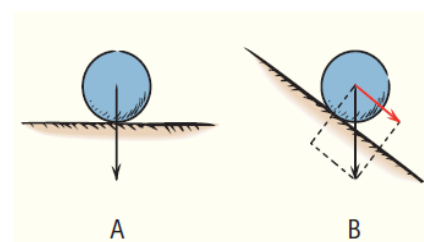
Table17. Students' scientific literacy level in answering question number 17

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	3	8	5	14	8	22	71.4 %
NSL	5	2	0	0	5	2	16.7 %
FSL	3	1	1	0	4	1	11.9 %

Question number 18

Given two cases, two balls were moving in the flat plane and inclined plane. In the flat plane, the weight of the ball did not do a work, while in the inclined plane the weight did a work, explain why.

Taken from Conceptual Physical science, Hewitt, P. G., Hewitt, L. A., & Suchocki, J. (2008).



This question was only a review concept that had been discussed in the classroom, the work is done by a force during displacement d , equal to $W = Fd \cos\theta$, θ is the angle between direction \mathbf{F} and \mathbf{d} . Students were expected to apply this concept to explain the question scientifically. The students' answers could be categorized as:

- Scientific Illiteracy (SI): Students had some misconceptions in explaining the question or did not recognize information. For example, "in the flat plane the ball is not moving, but in the inclined plane the ball is moving and rolling", "in picture A, the ball did not move, the contact force was in opposite direction with the weight, $\sum F = 0$; the weight acted down, consequently in the flat plane the weight did not influence anything but in picture B, the weight worked because it made the object move.
- Nominal Scientific Literacy (NSL) : gave the right fact but did not explain the question such as "the weight is perpendicular down, therefore in the inclined plane the weight will make the ball roll down".
- Functional Scientific Literacy (FSL): could explain based on the concept, "In a flat plane, the weight is perpendicular with the displacement, therefore the work is zero. On the other hand in an inclined plane the weight component along the plane is parallel with the displacement."

Table18. Students' scientific literacy level in answering question number 18

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	4	9	4	10	8	19	64.3 %
NSL	4	2	2	4	6	6	28.6%
FSL	3	0	0	0	3	0	7.1 %

Question number 19.

A physics instructor demonstrates energy conservation by releasing a heavy pendulum as shown in the picture, allowing it to swing back and forth. Did the pendulum hit him? What would happen if, he gave the pendulum a slight shove, as it left his nose? Explain it.



Picture taken from conceptual physics, Paul G Hewitt

This demo was very interesting and thrilling; usually many people make wrong predictions about what will happen. Students would be able to predict what will happen by applying the concept of work and energy that they have learned. The students' answers could be categorized as:

- Scientific Illiteracy (SI): In explaining what will happen, students wrote many mistakes in basic physics concepts or wrote a wrong fact. For example: "It will hit if the ball is being push hard with high speed, "No, because the mechanical energy and the weight between A and B are different and the ball will move faster and back to initial position if the ball was given an initial speed, the KE is bigger", "No, after releasing the ball he will go away and let the ball swing. When he released that ball by pushing, it has work and velocity".
- Nominal Scientific Literacy (NSL) : wrote inaccurate prediction and explanation, for example "the ball will hit , because it will go back to initial position and by pushing the work in pendulum becomes bigger", "it will hit if the velocity is constant and if the ball is being pushed, therefore the velocity will increase and it will hit him", "yes, because the ball will swing back and forth and if the ball is being pushed the ball will move faster and will hit him".
- Functional Scientific Literacy (FSL): wrote a correct prediction with appropriate explanation. For example "it will not hit, because the amplitude decreases and if the

ball is being pushed, the ball will hit because the amplitude is bigger”, “Because there is a damped force work at that pendulum, therefore when the pendulum goes back to initial position, that will not hit his face, because there is a friction”, “the speed is increasing, but the damped force constant therefore it could be predicted that the ball will hit his face”

Table19. Students’ scientific literacy level in answering question number 19

Level of scientific literacy	XA		XB		Total		Percentage
	Male (N=11)	Female (N=11)	Male (N=6)	Female (N=14)	Male N=17	Female N= 25	
SI	1	3	3	7	4	10	33.3 %
NSL	3	4	2	7	5	11	38.1%
FSL	7	4	1	0	8	4	28.6 %

5.2 Students’ approaches in answering the question

The study demonstrated that there were so many problems in students’ conceptual understanding. This fact was revealed from the methods of students in answering the question. Students’ approaches in problem solving do not show a conceptual understanding.

5.2.1 Imitating procedure

In question number 15, a similar question had been given before conducting group discussion. In the previous question, the initial velocity of the car was zero, therefore from the law of conservation of mechanic energy, we got the velocity formula for another point is $v = \sqrt{2gh}$. But in this question the car had the initial velocity, therefore this formula could not be used in this case. There were only 11 students who could answer the question correctly, and 12 students answered with the same way as the previous question. There were even 10 students who still made a mistake in solving the problem. This case showed that in solving the problem the students just followed the pattern, so they did not recognize that there were some differences.

Students could not solve the problem, if there was no example given before or no similar question. As an example, from the given displacement versus time graph for simple

harmonic motion, students were asked to determine the amplitude, period, and the displacement equation that were represented in the graph. To determine the amplitude is the easiest thing in this problem, just “pick” from the picture. The students had known the graph from the previous experiment such as determine the amplitude and period from the graph. But only 26 out of 40 students could determine the amplitude of the graph, even to determine the period, there were only 9 out of 40 students who could give the correct answer. Even though in the next session after the question was explained, the similar question was given but in the different type, determine the period from the harmonic motion equation $x(t) = 4 \cos(6\pi t)$, only 10 students could give the correct answer. The second question needed more steps to evaluate T with make a comparison $6\pi = 2\pi$, therefore $T = 3$. But in the second question given after further information about simple harmonic motion, the number of students that could answer this question should have been more. This approach was similar with pattern matching methods in Heller & Heller (2010). These methods emphasized memorizing and students got difficulties when facing a new type of question.

5.2.2 “Plug and Chug” method

In answering questions, many students still use the approach as introduced in the junior high school. These methods are also usual in many high school physics text books. As an example in the problem-solving task, the first step was to write the given variable in the question and then write the intended variable, and choose the formula that correlates between the two variables. For instance, in question number 9: Given two parallel springs with a mass 200 gram hooked into the spring, the mass is pulled and released so the system oscillates with a period of 2 seconds. What is the spring constant? Students wrote the known variables $m = 200 \text{ g}$, $T = 2 \text{ s}$, then wrote the spring period formula $T = 2\pi \sqrt{\frac{m}{k}}$, put the given variables into the formula and made a calculation to find the k value. Students might have directly answered the value k obtained from the equation, without knowing that the value of k contained in the formula in this case is the spring constant for two springs in parallel, if they only referred to the formula. Another problem was when the question involved more than one formula or multi-step questions, and just putting the known variable was not enough to solve the problem. Students needed to analyze the question.

Most of the students got difficulties in solving the non-routine questions, even an easy question. Such as question number 16, which asked for the work required to move the

object from one point to another point that have different heights in the contour map. From the lesson they had learnt before, work is equal to negative change in gravitational potential energy. Therefore from the contour map they should calculate the change in potential energy, because the teacher had explained what a contour map is. Actually this was a very basic question or one- step problem, just calculate work = - Δ Potential energy. But most students could not recognize that this problem had a solution related to work and potential energy. Only 6 out of 42 students could answer this question.

5.2.3 Difficulties in qualitative questions

Usually the questions in physics class involve numbers and equations, like math questions. The problems are usually related to one topic, and students calculate the variable or the quantity asked from the question using a certain formula. Most of students can answer this kind of question, especially the routine problem or one-step problem. Otherwise if the question has no numeric value, student cannot answer the question, even though it is a simple question.

In question number 14, students asked why in the case of a moving ball in the flat plane, the weight did not “do a work”, otherwise in the case of a moving ball in the inclined plane the weight did “do a work”. Actually this is a simple question, just applying the equation “ $W = F \times d \cos \theta$ ”, where θ is an angle between force and displacement. In the first case θ is 90° , $\cos 90^\circ = 0$ it makes W equal to zero. Otherwise in the second case θ is less than 90° , and therefore the work that results is not zero.

In addition if students were asked to explain some phenomena or make a conclusion from an equation or physics law, students got difficulties in explaining, especially if the question combined two or more concepts in one question. Question number 7 asked whether is there still gravity in a swimming pool and to give the reason why we are floating. Most students give inappropriate reasons why we are still floating in swimming pool associated with the presence of gravity. Even some students answered there is no gravity in the swimming pool. This is actually a simple question because they have learnt that everything on the earth is pulled by the earth’s gravity and as they know the gravity equation as well. To explain the reason why we are floating students seemed unable to correlate it with Archimedes principles, because at that time they learnt gravity. Even though Archimedes

principle was learnt in Junior High school and it became a common knowledge that everything in the water gets the buoyant force.

It seems that without number and formula students cannot solve the problem. Especially for qualitative questions, in which students are required to explain the phenomena or concept scientifically. They should comprehend the physics concept to answer the question, not only depend on the equation (Tao, 2011).

5.2.4 Know the symbol but not the context

In physics, there are so many symbols to represent physical quantities, therefore one symbol might represent two or more physical quantities. As an example, W in physics could be work or weight. Question number 20 proved that, when asked how much work is required to stop the car, there was a student who write the weight formula $W = m \times g$ and one student wrote $W = \frac{1}{2} Kx^2$ as work done by a spring. The first example was a completely different physics quantity, work and weight, and the second example was the same quantity but in a different case. Usually students make a mistake in doing a question about work and energy, because the same physical quantity.

Another example in the simple harmonic motion topic, students were asked to determine the period from the simple harmonic motion equation, and instead of calculating period from the equation, used the period for spring, and used the formula $F = m \times a$ when asked the frequency.

5.2.5 High dependence on equation

Sometimes in solving physics problems a formula is not always needed. The students can use their basic skills such as ratio, efficiency, percentage, etc. Question number 17 “the earth receives 1 kW/m^2 energy from the sun. A solar cell is able to convert 40% of solar energy it receives into electrical energy. How much energy is generated by 10 solar cells with an area of 2 m^2 each? This question can be solved by the formula from work and energy topics or only using basic skills. Only four students could answer correctly, three students followed the formula, one student could solve the problem by using basics math skill, while

another three students seemed to understand about the efficiency but made a mistake in calculation.

The problem-solving approach as shown above causes the students to not get a conceptual understanding in physics. Therefore although students did many problem-solving tasks, it did not build the students understanding, as shown in Kim & Pak (2001).

5.3 Problems in building scientific literacy

In this study, as a teacher researcher, I found many obstacles in building scientific literacy. The majority of the students did not have basic skills that are obligatory to enhance students' understanding.

5.3.1 Lack of basic skill in math and language

There are some students that have low levels in the basic math skills that are needed to solve and analyze the questions in physics tests. As an example in basic arithmetic $10 = 5 + a$, $a = 10 : 5 = 2$. Especially in class B most of the students had low basic math skill. Basic math skill is urgently required in physics class, because it a tool in physics problem solving.

Some students have a lack of basic language skills since they write a meaningless sentence in explaining or giving a reason for a question.

5.3.2 Lack of students' reading competency

Many students show the lack of reading competency in answering qualitative questions. If they are asked to explain some phenomena, the students repeat the statement in a question again but in a different editorial. For example in question number 1, "Why there is a difference in time for falling between the ball and feather in the chamber before the air is pumped out from the chamber? There was an answer from a student " before the air is

pumped out from the chamber, the bowling ball falls faster than the feather”. This did not answer the question, because this statement did not give the explanation.

Some students also could not recognize the information in the question. For example, question number 18: Given two cases, two balls were moving in a flat plane and an inclined plane. In the flat plane, we can say that the weight of the ball did not do a work, while in the inclined plane the weight did a work, why? There were eight students who answered because the ball in the flat plane did not move while the ball in the inclined plane was moving. Otherwise, there were four students who said that in the flat plane, there is no weight work. It reveals that the students could not take the information from the statement in the question.

5.3.3. Unable to Interpret the graph or make a graph

As an example in question number 6 in gravity topic, students were asked to make a gravitational fields graph versus distance from the center of a star. Only three from 40 students could answer it correctly, on the other hand when asked about the quantity of gravitational fields at a certain height compared to the gravitational fields at the earth’s surface, there were six students who could answer it.

Students also lacked ability to obtain the information from the graph, e.g. in question number 1 in SHM, given a displacement versus time graph, students were asked to determine the period of the oscillation and the displacement equation. This question was given immediately after explaining the topic without giving a problem task as usual. Only one student could answer correctly, while four other students seemed understand what to do, but made the wrong calculation.

5.3.4. Cannot explain the cause and effect of the phenomena scientifically

In physics, there are so many phenomena that correlate with everyday life. The students should be able to explain the daily phenomena using their understanding in physics

concepts that they have learned. Such as in an easy question in the review session: “Why is the moon’s gravity less than the earth’s?” This is a simple question, since they have learnt that the gravity is proportional to the mass of the object. They should answer because the mass of the moon is less than the mass of the earth. On the other hand some students gave many kinds of answer like, the moon is the earth’s satellite, far from the earth, there is no atmosphere on the moon, and the moon is not a planet.

Another example was question number 6, “If there is a gravity, why is the balloon floating?” Usually a balloon is filled with helium or acetylene gas (C_2H_2). In this problem the density of air, helium and the acetylene was given. Only three students justified with buoyancy against gravity, and none of them could prove it with the right calculation. While another eight students just gave the reason because the helium or acetylene are lighter than the air. Some of the students gave inappropriate explanations. The rest of the students did not answer (17 students) and this shows that most of the students cannot give a scientific explanation about physics phenomena.

Many students lack basic knowledge in science, especially in gravity topics. There were so many misconceptions revealed when asking about gravity, such as gravity was influenced by the air, the air influences mass, less gravity and big pressure in outer space make the water droplet round and floating. It seems that students made wrong conclusions from the video they had been watching. Some students still had misconceptions after they got the explanation from the teacher.

6 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to examine how to build scientific literacy through contextual learning in physics class. This study also examined how the students explained scientific phenomena. Since scientific literacy is an important competency in the 21st century, therefore physics teaching should build scientific literacy. Aligned with the definition of scientific literacy, thus, students should have a conceptual understanding in science, as well as in physics.

6.1 *Problems in building scientific literacy*

The study demonstrates that there are so many problems in students' conceptual understanding. This fact is revealed from the methods of students in answering the questions. Students' approaches in problem solving do not have a well-built conceptual understanding. Most of students answer the given questions based on the previous examples, and they tend to follow the procedure in similar questions from the previous example. This approach was similar with pattern found in Heller and Heller (2010). This method emphasizes memorizing, and students will encounter difficulties when facing a new type of question.

Students also have a great dependency on formulas or equations. If they have a problem, they tend to find what equation is needed. Usually, they determine the unknown and known variables and find the equation that can correlate with them, as identified by Wenning (2002). This often makes trouble when students face a complex question or a high order thinking skill question that requires more than one equation or one-step problem. Students also face difficulties if the question does not have a numeric value. For instance, if the quantity is given in the symbol form, most students cannot answer the question, even if it is a simple question.

Moreover, for a qualitative question which requires the explanation of a certain phenomenon of the physics concept scientifically, most students seem do not know how to give the explanation. It shows that most students learn physics only for the sake of answering

a certain test, and they do not understand the concept of it. Thus, in order to build students' scientific literacy, they should comprehend well the physics concept to answer the question (Tao, 2011).

6.2 *Lack of basic skills in building scientific literacy*

Since scientific literacy is the ability to engage in scientific-related issues and explain the phenomena scientifically, language skill is also an absolute skill to build the scientific literacy (Wellington, 2001). Besides, language is the tool for reading, collecting, analyzing the information as well as the tool for learning at school. From this result, it shows that lack of language skill causes difficulties in answering questions. Students cannot absorb the information from the text in a certain question, such as determining the known and unknown variables or the state of an object. In qualitative questions, students often repeat the statement in the question to answer the given questions, and they do not know how to explain the phenomena. In some cases, students write meaningless sentences to answer the question.

In addition, lack of basic math ability also causes students problems in answering the question, especially for a quantitative question. Students will have difficulties in solving the equation due to lack of basic math skill, since math is a crucial tool in physics. Another basic math skill such as reading and interpreting a simple graph is also necessary because the data in physics lesson sometimes provides graphical forms.

6.3 *Limitations*

In this research, students' scientific literacies were not well-developed yet, because building scientific literacy cannot be done in a short period of time. The way the teaching-learning process is performed also does not build scientific literacy yet. In addition, physics questions within students' examinations in Indonesia tend to be the repetition of the type of problem, so they are not really building the analytical skills of students. Changing this situation requires a continuous ongoing process, and it takes time.

6.4 *Recommendations*

This study reveals that students have lack of scientific literacy because there are so many basic problems in building students' scientific literacy, especially the basic skills in learning science, such as reading and basic numeracy. The school should have a policy in building students' basic skills in mathematics and language. Further research is recommended to be conducted in order to improve students' skills in language comprehension in science lessons and other subjects. The research should aim to overcome students' lack of language comprehension.

The school should make a special program to improve the students' ability in basic math for those who have the low numeracy skill. The program could be an extra tutorial for students after school. In addition, science teachers such as physics and chemistry teacher should give rich text problems to accustom students to solving problems using conceptual understanding. They also should start giving high order thinking skill questions in order to build the students' conceptual understanding. Teachers should not give routine questions such as repetitive questions in national examination anymore, which makes students only memorize the pattern. There should be a thorough change in teaching methods from teacher-centered based to student-' centered based for encouraging students to involve actively in building understanding of the concept. Learning by using students' as the center is truly effective and efficient, thus, teachers must be able to facilitate the development of students' conceptual understanding.

Furthermore, all teachers from any subject should use the teaching methods that really make the students use their critical thinking. Teachers should not only refer to local text books, but also refer to other countries' text books which have a high quality in education. Teachers may also take example tests from many sources, such as A level paper tests or IGCSEs. Regarding the lack of students' ability in answering questions, some changes are also needed to be proposed in the way that students answer the given question. One of the methods that can be applied practically is the attachment of a physical concept in the beginning of problem-solving process, and at the end of process trying to interpret the result in the physical concept, such as suggested by Heller et al. (1990).

Subsequently, to build students' ability in language skills, the teacher can also give some writing tasks in physics as suggested by Ritchie, Tomas, and Tones (2011). These writing tasks are expected to build students' scientific literacy, because it requires students

to explain the phenomena scientifically, to be familiar with scientific issues, and to build the understanding of science concepts.

Essentially, this study made the writer's paradigm shift. Initially, the author argued that the most important thing that teachers should master is teaching material, and teacher-centered based learning is a suitable method for science lessons, while student-centered based learning is only applied in experimental work. From this study, the author is aware that contextual learning is very suitable to be applied in the physics classroom to gain a comprehensive understanding of the students' physics concept, and therefore it will automatically build the students' scientific literacy.

I should apply contextual learning in my teaching methods in order to achieve students' scientific literacy. Further research should be done to explore more what the effect of contextual learning is in the physics classroom over a longer period of time, at least for one academic year. I should also make a change in the way of assessing students. Using alternative assessment is one of the choices to develop students' conceptual understanding, such as writing an essay or doing a project.

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APPENDIX 1

Students ' perception on physics.

Class : XI science

Gender :

Put the tick on the statement accordance to your opinion .

No	Statement	Totally disagree (1)	Disagree (2)	Undecided (3)	Agree (4)	Totally Agree (5)
1	I am interested in studying physics.					
2	I got no difficulties in studying physics					
3	In my opinion, there are many physics concept that applied in daily life					
4	I like to search for information or follow the new technology that related to science					
5	I prefer do an experiment rather than conventional teaching in studying physics					
6	Doing many exercise in physics helps me learn physics					
7	To comprehend the physics concepts help me to learn physics					
8	Memorizing the facts and concept help me to learn physics					
9	I dislike the mathematics calculation in physics					
10	Get a good grade is more important for me than comprehend the physics concept					

Please answer this question:

11. a. If physics is not a compulsory subject , do you still take the physics class ?

YES / NO

b. Give an explanation :

Because :
